WHITE PAPER REPORT on Using Nuclear Reactors to Search for a value of θ_{13}

July 23, 2003

DRAFT 1.1

1 Physics Opportunity- *Mike Shaevitz*

1.1 Introduction

1.2 Road Map for the Future of Neutrino Oscillation Measurements

1.2.1 Stage 0: The current program

1.2.2 Stage 1: Measuring or limiting θ_{13}

1.2.3 Stage 2: Observe CP violation and matter effects

1.3 How do reactor oscillation experiments fit in?

2 Theoretical Motivation

P. Huber, M. Lindner, T. Schwetz, W. Winter

2.1 Introduction

general issues ....
status quo: 2x2 neutrino oscillation...
θ_{13} is next important parameter:
- establish 3nu effects
- controls leptonic CP violation
- ....

2.2 Theoretical expectations for θ_{13}

- how small can θ_{13} be?
- mass models, RGE, ...
- ...

2.3 Systematics of a 2 detector setup

Important principle systematics questions to be answered in this section:
- Why two detectors and not one?
(normalization controlled ...)
- Why two identical detectors?
(small uncorrelated errors ...)
- Why one of those two at a short baseline without oscillations?
(shape error unimportant ...)
- How big should the detectors be?
(systematics differences between Reactor-I and Reactor-II)
- At which baseline should the far detector be?
- At which baseline should the near detector be?

2.4 Comparison to superbeams and synergies

Comparison to superbeams on much simpler/shorter level than in our paper:
- degeneracy-free measurement possible
(compare formula to superbeam formula)
- reactor experiments especially for large α better
- some clear statements in form of new bar charts (?)
about the synergies (less complicated than our paper)
- How do the reactor experiments strategically fit in the long-baseline discussion?

3 Other Reactor Experiments

3.1 Chooz

3.2 KamLAND

3.2.1 Introduction

3.2.2 Experiment Description

3.2.3 Measurement of neutrino flux

3.2.4 Calibration and event reconstruction

3.2.5 Event selection

3.2.6 Background estimation/subtraction

3.2.7 Systematics

3.2.8 Determination of oscillation parameters

3.2.9 Results and Prospects

4 Palo Verde

4.1 Introduction

4.2 Experiment Description

4.3 Data Analysis

4.3.1 Measurement of neutrino flux

4.3.2 Calibration and event reconstruction

4.3.3 Event selection

4.3.4 Background estimation/subtraction

4.3.5 Systematics

4.3.6 Determination of oscillation parameters

4.4 Results

5 Possible Sites - *Jonathan Link*

5.1 Top Performing Reactors Worldwide

5.2 Reactors Sites Under Consideration

A brief description of the pros and cons of all reactors sites under consideration. This includes Kashiwazaki-Kariwa, Paluel, Braidwood, Byron, Limerick, Peach

Reactor Site	Country	Avg MW_{th}	Max MW_{th}
Brokdorf	Germany	3900	4214
Emsland	Germany	3892	4097
Grohnde	Germany	3858	4184
Grand Gulf	US	3505	3833
Grafenrheinfeld	Germany	3357	3936
Wolf Creek	US	3211	3565
Perry	US	3199	3758
Callaway	US	3176	3565
Leibstadt	Swiss	3130	3511
Waterford	US	3152	3390
Watts Bar	US	3049	3411
Unterweser	Germany	3117	4126
Seabrook	US	2924	3411
Vandellos	Spain	2882	3181
Kruemmel	Germany	2868	3851
Confrentes	Spain	2858	3160
Hope Creek	US	2794	3339
Fermi	US	2750	3430
River Bend	US	2676	3039
Trillo	Spain	2672	3119
Columbia	US	2567	3486
Tokai	Japan	2086	3219
Krasnoyarsk	Russia	1600(?)	2000(?)

Table 1: Power performance for single reactor sites around the world.

Reactor Site	Country	Avg MW_{th}	Max MW_{th}
South Texas Project	US	6864	7600
Civaux	France	6799	9135
Chooz	France	6795	8872
Gundremmingen	Germany	6734	7865
Braidwood	US	6491	7172
Vogtle	US	6456	7130
Byron	US	6442	7172
Browns Ferry	US	6377	6916
Limerick	US	6365	6916
Isar	Germany	6313	6985
Peach Bottom	US	6290	6916
Sequoyah	US	6209	6822
Penly	France	6197	8088
Philippsburg	Germany	6187	6976
Susquehanna	US	6161	6978
Golfech	France	6136	7977
Catawba	US	6116	6822
Nogent	France	6111	7977
San Onofre	US	6061	6876
Diablo Canyon	US	6043	6749
Comanche Peak	US	5986	6916
St. Alban/St. Maurice	France	5910	8082
Neckar	Germany	5881	6452
McGuire	US	5880	6822
Flamanville	France	5879	8088
Biblis	Germany	5528	7388
Asco	Spain	5496	6013
Belleville	France	5377	7977
Kuosheng	Taiwan	4749	5764
Angra	Brazil	4547	5873
Indian Point	US	4467	6096
La Salle	US	4323	6978
Salem	US	4281	6918
Ignalina	Lithuania	3985	8778
D.C. Cook	US	3281	6661
Millstone	US	3271	6111

Table 2: Power performance for double reactor sites around the world.

Reactor Site	Country	Cores	Avg MW_{th}	Max MW_{th}
Kashiwazaki-Kariwa	Japan	7	20302	24029
Yonggwang	S. Korea	6	16393	17264
Gravelines	France	6	12458	16696
Zaporozhe	Ukraine	6	12202	17557
Catternom	France	4	12113	15942
Paluel	France	4	11901	16176
Ohi	Japan	4	11269	13782
Palo Verde	US	3	10570	11552
Fukushima II	Japan	4	10384	12875
Fukushima I	Japan	6	10181	13741
Darlington	Canada	4	9028	10932
Chinon	France	4	8653	11166
Blayais	France	4	8644	11131
Cruas	France	4	8586	11190
Takahama	Japan	4	8439	9925
Genkai	Japan	4	8330	10177
Kori	S. Korea	4	8314	9203
Ringhals	Sweden	4	8307	10841
Tricastin	France	4	8284	11178
Bruce	Canada	4	8080	10710
Tihange	Belgium	3	8075	9127
Hamaoka	Japan	4	8031	10584
Forsmark	Sweden	3	7773	9408
Dampierre	France	4	7753	10967
Bugey	France	4	7728	10897
Leningrad	Russia	4	7642	11705
Balakovo	Russia	4	7520	11705
Kozloduy	Bulgaria	6	6618	11002
Kursk	Russia	4	6577	11705

Table 3: Power performance for multi reactor sites around the world.

Bottom, Penly, Diablo Canyon, Flamanville, Kuosheng, Angra, La Salle, Wolf Creek, and Krasnoyarsk.

6 Tunneling

6.1 Introduction

6.2 Underground Site Requirements

- intend to include a brief discussion of my current understanding of the basic needs of the underground experimental facilities, notably relating to the size of the openings, safety and the environment.

6.3 Geology as it Influences the Selection of an Underground Site

- intend to discuss the key geologic, groundwater and geotechnical criteria that need to be considered in selecting an underground site for this experiment.

6.4 Design and Construction Considerations

- intend to make recommendations as to how one might proceed, including a few comments on key steps in the planning process (I'd like to tie any commentary on planning to the Experiment's schedule - based on the tightness of the schedule I might make some recommendations on strategies for teaming and contracting-out the work).

6.5 Summary

- I intend to stress the near-term need for good site data which is needed to support of the site selection process. The same data sets will be needed to support the identification of a cost effective construction option(s) at any given site and the development of reliable construction cost estimates and schedules. I'm thinking you will need good construction cost and schedule data early in order to support the proposal process.

7 Shaft Hole - *Fumihiko Suekane*

7.1 Why Shaft Hole?

7.2 Available Techniques

7.3 Rough Cost Estimations

8 General Considerations - *Maury Goodman*

8.1 Introduction

8.2 Basic Design of the Experiment

8.3 Controlling Systematic Effects

8.4 Ultimate Sensitivity

9 Optimal Baseline Distances - *Karsten Heeger and David Reyna*

9.1 Oscillation vs. L/E

9.2 Reactor Spectra

9.3 Statistical use of overall Rate and Shape information

9.4 Influence of Systematic Effects

9.5 Figure of Merit

10 Backgrounds and Detector Depth Issues

11 Calibration

11.1 General Considerations

11.1.1 Basic detector characteristics and detector simulation

11.1.2 Energy reconstruction

11.1.3 Vertex/track reconstruction

11.1.4 Particle ID

11.1.5 Efficiency

11.2 Special Considerations for a Multi–Detector Experiment

11.3 Calibration System Design

11.3.1 Radioactive sources

11.3.2 Light flasher sources

11.3.3 Cosmics and natural radioactivity

11.3.4 Source deployment

11.4 Calibration R&D

12 Detector Design

13 Systematics

14 Comparison With Proposed Long-Baseline Accelerator Experiments - *Mike Shaevitz*

14.1 Apperearance versus Disappearance Measurements

14.1.1 Degeneracies in the LBL measurement (This may be covered elsewhere)

14.2 Comparison of Sensitivites to θ_{13}

14.3 Optimizing the Experimental Program

15 Safety

15.1 Safety Planning

15.2 Civil Construction

15.3 Material Handling

16 Outreach

David Demuth

17 Summary

18 Appendices

A Kasiwazaki - *Fumihiko Suekane*

A.1 Introduction

A.2 The Kashiwazaki multi reactor complex

A.3 Detectors

A.4 Expected Sensitivity

B Zheleznogorsk one reactor underground site

V. Martemianov
Kurchatove Institute, Russia

- Reactor operation is free for collaboration - Reactor operational run: $\sim$ 50 days ON, $\sim$ 8 days OFF - The underground ($\sim$600 m.w.e.) infrastructure: Two halls for detectors at the distances from the reactor of $\sim$110 m (15x15x15 m) and at $\sim$1000m (15x100 x 11m high); the far hall may require renting). - Power supply, ventilation, safety, railways to both halls. - The Kr2Det project is supported by MCC and "Kurchatov Institute" Directors. Joining of JINR (Dubna) and PNPHI (St.- Petersburg) to the Project is under discussion now. - MCC (the Mining & Chemical Combine) can build the detector vessels and passive shield of the detectors.

Zheleznogorsk conditions for living

- One can live in a guesthouse, at a hotel or hire a flat. - No problems with phones, bank accounts, food, renting cars. - High level personal safety (closed city) - MCC is ready to provide an office room in the city with telephones and internet connection. - Weather is comfortable, air is dry, many sunny days.

C Site specific ideas for reactors in Europe

D Site specific issues for Diablo Canyon (California)

References